

Parasitic plant in natural *Boswellia papyrifera* stands at Humera, Northern Ethiopia

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Abstract: In *Boswellia papyrifera* (Del.) Hochst natural stands, we studied the association of parasitic plants with *B. papyrifera* trees from which frankincense was tapped and marketed for domestic and export markets. Data on the rate of infection of parasitic plants on *B. papyrifera* was collected in three transects located at separate locations around Baha kar, northern Ethiopia. Each transect had ten circular sample plots of 400 m² and separated by 100 m. Species composition, DBH, height, crown diameter, number of main, secondary and tertiary branches and number of parasitic plants on individual trees were recorded. Sixteen tree species were recorded in the combined sample plots. The parasitic plant associated with *B. papyrifera* was identified as *Tapinanthus globiferus*. This parasite infected 38% of *Boswellia* trees in sample plots. The infection rate of the parasitic plant varied from 1 to 33 per *Boswellia* tree. The infection of *T. globiferus* on *B. papyrifera* was predominantly limited to tertiary small branchlets arising from secondary branches; parasitic plants were absent on thick main and secondary branches. In all plots, infection

of *T. globiferus* was exclusively limited to *Boswellia* trees. The influence of *T. globiferus* parasitism on growth of *Boswellia* trees and its influence on yield of incense production needs further investigation. Management of natural stands for frankincense production should include measures to reduce infection by *T. globiferus*.

Keywords: *Boswellia papyrifera*, parasitic plant, *Tapinanthus globiferus*, Humera, Ethiopia

Introduction

Boswellia papyrifera (Del.) Hochst is a deciduous, multipurpose tree species that attains heights to 16 m and has thick branches tipped with clusters of leaves and a rounded crown (Groenendijk et al. 2012; Bekele 1993). The genus is widely grown in arid regions of tropical Africa (Ogbazghi et al. 2006) such as Nigeria, Cameroun, Central African Republic, Chad, Sudan, Uganda, Eritrea and Ethiopia (Vollesen 1989), and in parts of the Arabian and Indian sub-continent (Ogbazghi et al. 2006). In Ethiopia it is distributed in Tigray, Amhara, Oromiya, Afar and Benishangul-Gumuz Regional States often on steep rocky slopes, lava flows or sandy river valleys (Lemenih and Kassa 2011; Bekele 1993; Vollesen 1989). Despite its ecological and economic importance (Kassa et al. 2011; Worku et al. 2011; Rijkers et al. 2006; Gebrehiwot et al. 2003), the population of *B. papyrifera* declined at alarming rate as a result of expansion of agriculture, overgrazing, fire, over-tapping and improper tapping practices, and insect infection (Rijkers et al. 2006; Gebrehiwot et al. 2003).

Parasitic plants are taxonomically diverse (Shen et al. 2006) and can be classified as root or shoot parasites or hemi- or holo parasites, based on their site of attachment and presence or absence of chloroplasts, respectively. In either case the growth of parasitic plants partially or completely relies on the translocation of host plant for dissolved minerals, nutrients and water through penetration of host's vascular systems by haustoria development (Watson 2009; Press and Phoenix 2005).

The association between parasitic flowering plants and *Bos-*

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Boswellia papyrifera trees in Ethiopia has not been adequately studied. Therefore, we aimed to identify parasitic species, quantify levels of infections, and describe the association of tree characteristics with infection of *B. papyrifera* in natural stands at Humera, northwestern Ethiopia.

Materials and methods

Study area

A field survey was conducted in September–October 2011 and

2012 in Baha ker sub-district, 50 km East of Humera town, in Qefta Humera District of western Tigray Zone, Ethiopia (Fig. 1). It was estimated that about 97,500 ha of the district were predominately covered by *Boswellia papyrifera* species. The area is characterized by a pronounced dry season with mean annual rainfall of 952 mm and temperature of 22.3°C (Gebrehiwot et al. 2003). In some localities, the forest of *B. papyrifera* was encroached by the expansion of mechanized sesame and cotton farming. This study was conducted at 797–860 m asl. At the zonal level soil types included Vertisols, Leptosols, Regosols, Luvisols and Fluvisols.

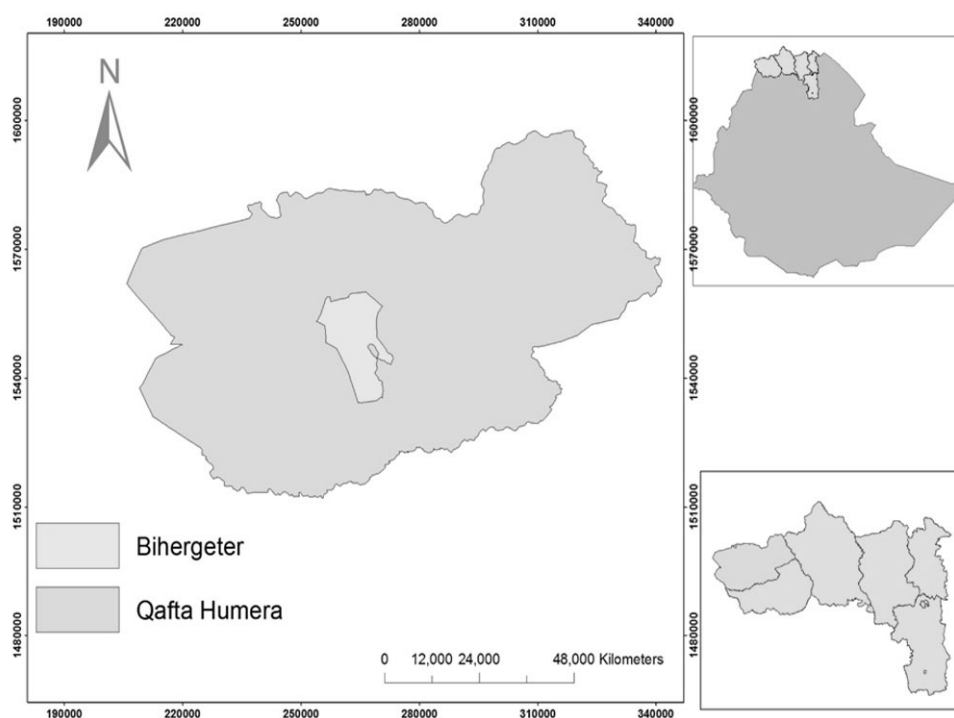


Fig. 1: Study area

Sample collection

In 2011, a reconnaissance survey was completed to identify representative sites with large *Boswellia* population stands in Baha kar sub-district. In the following year, three 1-km long transect lines were demarcated at three separate localities, each with 10 circular plots of 400 m² separated by 100 m from edge to edge. Tree height, crown diameter and diameter at breast height (DBH) were recorded within each study plot. Numbers of dead trees, presence or absence of tapping scars, numbers of main and secondary branches, and locations of parasitic plant infection with respect to the branches of each tree were recorded for *B. papyrifera*. In this study branches that arose from the main bole of the stem were defined as main; those arising from main as secondary and those arising from secondary as tertiary branches. Specimens of the parasitic plant were collected and sent to the National Herbarium of Addis Ababa University for species identification.

tification.

Statistical analysis

The proportional presence of parasitic plants was calculated for *B. papyrifera* host trees. Levene's test was used to test the homogeneity of variance of measured responses for trees with and without parasitic plants. Independent sample t-test was used to compare the proportion of infected and non-infected sample trees as a function of DBH, height, crown diameter, number of main and secondary branches. Pearson correlation was used to assess the relationship between presence of parasitic plants and the above parameters. One-way analysis of variance (ANOVA) was used to compare species at densities >5 trees per hectare with respect to DBH, height and crown diameter. Where the overall ANOVA detected significant difference, Post Hock mean separation procedure was used to separate the means. Data were analyzed using SPSS ver.16.

Results

Species composition in sample plots

In the 30 sample plots we identified a total of 330 trees of 16 species and 10 families (Table 1). Plots were dominated by *B. papyrifera* and the numbers of dead trees were three, two and one of *B. papyrifera*, *S. kunthianum* and *A. seyal*, respectively. All *B. papyrifera* trees in the sample plots had scars due to several rounds of tapping to produce frankincense. Beginning in 2011 all *Boswellia* trees administered by the National Gum and Resin Enterprise of Ethiopia that have been tapped for several years in succession are required to be rested for a period of five years without tapping.

Identification and characteristics of the parasitic plant

The plant parasitizing *B. papyrifera* was identified as *Tapinanthus globiferus* (A.Rich.) Tiegh. It has alternate to sub-opposite leaves with chlorophyll. The sub-globose green fruits have white spots when immature and changing to bright red berries as the plant matures. The flowers and berries of *T. globiferus* remain intact for some time in the dry periods where *B. papyrifera*

shades *T. globiferus* leaves. Thus berries were available to birds as forage. We frequently observed initiation of several clumps of black, massive, woody swellings of *T. globiferus* on branches of *B. papyrifera* (Fig. 2). Severely infected branches were frequently dead and later fell to the ground.

Table 1: List of species in the study plots

Species	Family	Trees per ha
<i>Acacia seyal</i>	Mimosaceae	2.5
<i>Anogeissus leiocarpus</i>	Combretaceae	82.5
<i>Boswellia papyrifera</i>	Burseraceae	425
<i>Combretum collinum</i>	Combretaceae	72.5
<i>Combretum molle</i>	Combretaceae	30
<i>Dichrostachys cinerea</i>	Mimosaceae	30
<i>Lannea sp.</i>	Anacardiaceae	35
<i>Pterocarpus lucens</i>	Papilionaceae	32.5
<i>Stereospermum kunthianum</i>	Bignoniaceae	17.5
<i>Sterculia setigera</i>	Sterculiaceae	2.5
<i>Terminalia schimperiana</i>	Combretaceae	10
<i>Warburgia melanoxylon</i>	Rutaceae	60
<i>Ximenia americana</i>	Olacaceae	7.5
<i>Zizyphus mucronata</i>	Rhamnaceae	2.5
<i>Terminalia brownie</i>	Combretaceae	5
<i>Zizyphus spina-christi</i>	Rhamnaceae	10



Fig. 2: *Tapinanthus globiferus* infection on branches of *B. papyrifera*

Parasitic plants on *Boswellia papyrifera*

Of 170 *B. papyrifera* trees in all sample plots, 38% were infected by *T. globiferus*. In the preliminary non-structured random sampling conducted in 2011 at two of the three plots which were later selected for sampling sites and 41% (146/356) of *Boswellia*

trees were similarly infected by this parasite. In both samples, infection of *T. globiferus* was exclusive to *B. papyrifera*. Infection was entirely restricted to tertiary branches, whereas none of the main and secondary branches were parasitized. Even among tertiary branches, most infections were restricted to the distal branchlets of the host trees.

Although the bivariate correlation analysis showed that pres-

ence of parasitic plants on tertiary branches was significantly correlated with DBH and crown diameter (Table 2). Further analysis with the effect of DBH constant clearly showed that the presence or absence of parasitic plants on *B. papyrifera* was not related to height, crown diameter, or number of main and secondary branches at $p < 0.05$ (Table 3). The absence of at least one parasitic plant in the main and secondary branches of *B. papyrifera* prevented calculation of bivariate correlation.

Tree heights in sample plots were similar for *B. papyrifera*, *A. leiocarpus* and *S. kunthianum*. Crown diameters differed significantly between *B. papyrifera*, *A. leiocarpus*, *C. collinum*, *C.*

molle and *Dichrostachys cinerea*. *A. leiocarpus* and *Terminalia schimperiana* differed significantly in DBH (Table 4).

In Baha kar sub-district a number of avian species have been recorded, including Abyssinian Roller (*Coracias abyssinica*), Black-headed Oriole (*Oriolus larvatus*) and weavers such as Northern Red Bishop (*Euplectes capensis*). Among these *C. abyssinica* frequently landed and spent time on the branches of *B. papyrifera*. Bird nesting was commonly observed on the branches of *Zizyphus* species that grew along riversides. None of the *Boswellia* trees within or outside the study area had any bird nests.

Table 2: Bivariate correlations

	DBH			Height			Crown diameter		
	Pearson correlation	Sig. (2-tailed)	N	Pearson correlation	Sig. (2-tailed)	N	Pearson correlation	Sig. (2-tailed)	N
Height	0.532**	0	170						
Crown diameter	0.745**	0	170	0.413**	0	170			
Parasitic plant	0.283**	0	170	0.104	0.179	170	0.212**	0.006	170

**Correlation is significant at the 0.01 level (2-tailed)

Table 3: Partial correlations

DBH	Height			Crown diameter			Tertiary Branch		
	Correlation	Sig. (2-tailed)	df	Correlation	Sig. (2-tailed)	df	Correlation	Sig. (2-tailed)	df
Height	1		0	0.029	0.711	167	-0.058	0.454	167
Crown diameter	0.029	0.711	167	1		0	0.001	0.992	167
Parasitic plant	-0.058	0.454	167	0.001	0.992	167	1		0

* Correlation is significant at the 0.05 level (2-tailed)

Table 4: Crown diameter multiple comparisons of species with respect to DBH, height and crown diameter

Species (i)	Species (j)	DBH		Height		Crown diameter	
		Mean ($X_i - X_j$)	Sig. level	Mean ($X_i - X_j$)	Sig. level	Mean ($X_i - X_j$)	Sig. level
<i>Boswellia papyrifera</i>	<i>Anogeissus leiocarpus</i>	0.347	0.783	0.382	0.278	-1.796(*)	0.000
	<i>Combretum collinum</i>	10.871(*)	0.000	2.032(*)	0.000	0.9410(*)	0.001
	<i>Combretum molle</i>	11.358(*)	0.000	2.636(*)	0.000	1.276(*)	0.002
	<i>Dichrostachys cinerea</i>	22.109(*)	0.000	5.844(*)	0.000	2.900(*)	0.000
	<i>Lannea sp</i>	7.409(*)	0.000	1.773(*)	0.001	0.2163	0.568
	<i>Pterocarpus lucens</i>	5.019(*)	0.009	1.940(*)	0.000	0.0226	0.954
	<i>Stereospermum kunthianum</i>	10.140(*)	0.000	1.094	0.126	0.627	0.234
	<i>Terminalia schimperiana</i>	-0.215	0.938	2.094(*)	0.007	-0.3075	0.587
	<i>Warburgia melanoxylon</i>	9.801(*)	0.000	2.623(*)	0.000	0.2029	0.495
	<i>Ximenia americana</i>	18.606(*)	0.000	5.094(*)	0.000	1.3175	0.098
	<i>Zizyphus spina-christi</i>	17.428(*)	0.000	3.994(*)	0.000	1.384*	0.026

*Correlation is significant at 0.05 level (2-tailed)

Discussion

In Baha kar sub-district nearly 40% of *B. papyrifera* trees were infected by *T. globiferus*. Nigussie (2008) studied the same host species in another district and sub-district of Tigray and reported

that *T. globiferus* infected *Boswellia* but affected different percentages of trees, viz. 13.9% in open grazed land of Qafta-Humera-Tekeze District and 63.8% in open forest and 57.4% in closed forest of Tanqua-Abergele-Jijike District. Our findings on the importance of tree height and crown diameter of *B. papyrifera* in *T. globiferus* infection agreed with Nigussie (2008) and disprove the hypothesis that host characteristics are

unrelated to infection of *T. globiferus* in Bah kar. The greater infection of parasitic plants on the tertiary branches than on the main and secondary branches of *B. papyrifera* might be due to the physiological, biochemical and physical compatibility of branches and suitability of diameters of the host branch or twigs for landing and perching of fruit dispersing birds (Roxburgh and Nicolson 2005; Lopez de Buen and Ornelas 2002; Norton and Ladley 1998; Yan and Reid 1995).

T. globiferus showed greater host specificity in Ethiopia than in Burkina Faso. In Burkina Faso, *T. globiferus* infected nearly all woody species that are common to both countries. In Ethiopia, however, no infection was observed except in *B. papyrifera*. This inconsistency between the two countries might be linked to differences in host abundance (Devkota et al. 2010), tree height (Aukema and Martinez del Rio 2002), physiological, biochemical and physical compatibility of branches (Roxburgh and Nicolson 2005; Lopez de Buen and Ornelas 2002; Norton and Ladley 1998; Yan and Reid 1995), host suitability for haustorial penetration and growth (Yan 1993), abundance, availability and behavior of avian dispersers (Roxburgh and Nicolson, 2005; Devkota et al. 2010; Martinez del Rio et al. 1996; Lopez de Buen and Ornelas 2001); the length of time the host and the parasite have been together (Norton and De Lang 1999); conspicuousness and nutritional value of mistletoe seeds (reviewed in Lopez de Buen and Ornelas 2001; Ladley and Kelly 1996); or forest disturbance and climatic factors such as light, temperature, and moisture (Devkota et al. 2010). Differences in crown diameters between trees and the availability of fruits of *T. globiferus* on infected *B. papyrifera* branches during the period of scarcity of fruits and seeds enable seed-dispersing birds to frequently visit, and re-infect *Boswellia* trees by depositing more *T. globiferus*-fruits on its branches than on branches of other tree species (Gill and Hawksworth 1961; Kartoolinejad et al. 2007).

Conclusion and recommendation

In Ethiopia, several factors are now affecting the survival rate of *B. papyrifera* in its natural range. The additional pressure exerted by *T. globiferus* along with 8–12 rounds of tapping of the host during the dry and leafless season (Groenendijk et al. 2012; Gebrehiwot et al. 2003) definitely impair the growth, vigor and disease susceptibility of *B. papyrifera* in natural stands (Watson 2009; Puustinen and Mutikainen 2001; Luttge et al. 1998). Furthermore the infection of *T. globiferus* on branches that produce seeds might have reduce the quality and/or quantity of seeds produced by the host. Therefore, in addition to immediate interception of the infection through pruning of infected branches, better understanding is needed of the ecophysiology of the mistletoe/host-association and its relation to environmental factors during periods of drought stress. Further study is also needed of fruit dissemination by birds.

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